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Advances in gas chromatography, mass spectrometry, and air sampling techniques have been unveiling a complex world of biological interactions mediated by volatile chemicals. Volatile organics from plants are particularly significant in such interactions. Insect behaviors such as host-finding, feeding, and oviposition are frequently regulated by plant volatiles (Tumlinson, 1988). The proliferation of many plant pathogens is inhibited by certain volatile emissions from plants (Hamilton-Kemp et al., 1992). Interplant communication by volatile compounds has been demonstrated. Methyl jasmonate emissions from *Artemisia tridentata* can induce the synthesis of proteins in nearby tomato plants which inhibit the proteinases of pathogens and insects (Farmer et al., 1992). Plant volatiles affect the edible quality of fruits and vegetables (Teranishi and Kint, 1993) as well as the quality of earth's atmosphere (Chameides et al., 1988). Continued investigation of volatile emissions from plants promises to reveal countless other fascinating roles played by volatile chemicals within plant and animal communities and their environments.

The National Aeronautics and Space Administration's (NASA) objective of developing a biologically-based Controlled Ecological Life Support System (CELSS) for producing crops for food during long-duration space missions faces many challenges, including control and monitoring of air quality. Volatile emissions from plants merit particular attention due to possible effects on air quality and the plants themselves. Moreover, some plant volatiles alter human behavior. The essential oil of lavender possesses sedative properties and a mixture of orange terpenes increases motility (Buchbauer et al., 1993).

The objective of the present study was to measure qualitatively and quantitatively the emission of volatile organics from 'Waldmann's Green' leaf lettuce cultivated under different levels of light intensity, photoperiod, and temperature. Crop production in CELSS will occur under controlled levels of light and temperature and consequently, determination of how these environmental conditions influence volatile emissions is essential.

To achieve the experimental objective, a Controlled Environments LTD Model EF7 growth chamber (Winipeg, Canada) was modified to enable sampling of volatile emissions from individual hydroponically-grown lettuce plants. By enclosing plants with a clear glass sampling vessel in which temperature was controlled and light reduction was minimal, the sampling technique was nondestructive and relatively noninvasive. Air samples were collected and analyzed by gas chromatography-mass spectrometry (GC-MS).

A Controlled Environments LTD Model E15 growth chamber was fitted with a similar hydroponic system in which lettuce plants were cultivated under the same conditions as in the modified growth chamber. Shoot fresh and dry weight relative growth rates were not different between chambers. Consequently, lettuce plants were regularly harvested from this growth chamber for collecting biomass data. A statistical procedure

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was developed to indicate variability of mean total volatile emission/shoot dry weight ratios for the data measured independently in the separate chambers.

The lipoxygenase pathway products (Z)-3-hexenal, (Z)-3-hexenol, and (Z)-3-hexenyl acetate were emitted during the first 30 min of the dark period during each light-dark cycle. These same compounds were detected when lettuce was mechanically perturbed. The treatment mean total volatile emission/shoot dry weight ratios were highest when light intensity was highest, photoperiod was longest, and temperature was highest. In green leaves, activities of the C_6 aldehyde forming enzyme system during the summer were highest when solar radiation and temperature were highest (Hatanaka et al., 1987).

(Z)-3-hexenal and (Z)-3-hexenol exert antifungal properties against *Botrytis cincerea*, *Rhizoctonia solani*, *Fusarium oxysporum*, *Didymella lycopersici,* and *Cladosporium fulvum* (Urbasch, 1984). This underscores the notion that plant volatiles can be advantageous in crop systems, and a CELSS system which efficiently filters these compounds from the air may render crops more susceptible to disease. A closed system such as CELSS models natural systems and will benefit to the extent it can exploit the desirable characteristics of natural systems. If airborne C_6 compounds are deemed to be undesirable, prevention or filtration of emissions must be considered. One approach that should be tested is a gradual rather than instantaneous reduction in light intensity from the light to the dark period. A filtration strategy might capitalize on the possibility noted by Arey et al. (1991) that oxygenated hydrocarbons are lost when air samples are collected in evacuated stainless steel cannisters.

The chemical pathway by which (Z)-3-hexenal, (Z)-3-hexenol, and (Z)-3-hexenyl acetate are produced has the capacity to generate (E)-2-dodecenedioc acid (traumatic acid, the "wound hormone"), which induces cell proliferation, and jasmonic acid, which along with its methyl ester, methyl jasmonate, induces proteinase inhibitors (Farmer and Ryan, 1990). Jasmonic acid is weakly volatile and methyl jasmonate relatively more volatile, but neither were detected in this study. The biological significance of these compounds is striking; future research would do well to determine whether they are in fact produced in lettuce when the chemical conversions leading to the emission of the C_6 compounds are occurring.

Several possible directions are inviting for future investigation. Other environmental influences such as light quality, nutrient solution composition, temperature and pH, and CO_2 enrichment should be investigated. Measurement of volatile emissions during catastrophic environmental changes also would be beneficial. Additionally, study of volatile emissions during a gradual reduction in light intensity from the light period to the dark period might provide more insight into how the emission of (Z)-3-hexenal, (Z)-3-hexenol, and (Z)-3-hexenyl acetate is regulated by the onset of the dark period in controlled environments.

Perhaps one of the most exciting areas of plant volatile research is that of the functions of volatile organics in regulating plant communities. The work of Farmer and Ryan (1990, 1992) advances the concept that chemical interactions among plants may be ongoing, vital activities. A closed system such as that of CELSS would especially benefit from this type of research. Ideally, plant-plant interactions could be exploited to meet yield, disease resistance, and other production objectives of CELSS.

Literature Cited

Arey, J., Winer, A.M., Atkinson, R., Aschmann, S.M., Long, W.D., and C.L. Morrison. 1991. The emission of (Z)-3-hexen-1-ol, (Z)-3-hexenylacetate, and other oxygenated hydrocarbons from agricultural species. Atmos. Environ. 25:1063-1075.

Buchbauer, G., Jager, W., Jirovetz, L., Ilmberger, J., and H. Dietrich. 1993. Therapeutic properties of essential oilsand fragrances, p. 159-165. In: R. Teranishi, R.G.Buttery, and H. Sugisawa (eds.), Bioactive volatile compounds from plants. American Chemical Society, Washington, DC.

Chameides, W.L., Lindsay, R.W., Richardson, J., and C.S. Kiang. 1988. The role of biogenic hydrocarbons in urban photochemical smog: Atanta as a case study. Science 241:1473-1475.

Farmer, E.E., Johnson, R.R., and C.A. Ryan. 1992. Regulation of expression of proteinase inhibitor genes by methyl jasmonate and jasmonic acid. Plant Physiol. 98:995-1002.

Farmer, E.E., and C.A. Ryan. 1990. Interplant communication:Airborne methyl jasmonate induces synthesis of proteinase inhibitors in plant leaves. Proc. Natl. Acad. Sci. 87:7713-7716.

Farmer, E.E., and C.A. Ryan. 1992. Octadecanoid-derived signals in plants. Trends Cell Biol. 2:236-241.

Hamilton-Kemp, T.R., McCracken, C.T., Loughrin, J.H., Andersen,R.A., and D.F. Hildebrand. 1992. Effects of some natural volatile compounds on the pathogenic fungi *Alternaria alternata* and *Botrytis cinerea*. J. Chem. Ecol. 18:1083-1091.

Teranishi, R., and S. Kint. 1993. Bioactive volatile compounds fromplants: an overview, p. 1-5. In: R. Teranishi, R.G. Buttery, and H. Sugisawa (eds.), Bioactive volatile compounds from plants. American Chemical Society, Washington, DC.

Tumlinson, J.H. 1988. Contemporary frontiers in insect semiochemical research. J. Chem. Ecol. 14:2109-2130.

Urbasch, I. 1984. Production of C_6-wound gases by plants and the effect on some phytopathogenic fungi. Z. Naturforsch. 39c:1003-1007.